Analysis & Design of a Power Plant For a Proposed Department Store and Office Building

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Analysis and design of a
power plant for a proposed

ANALYSIS AND DESIGN OF A POWER PLANT
FOR A
PROPOSED DEPARTMENT STORE
AND OFFICE BUILDING.

A THESIS PRESENTED

by

Walter Alonzo Ratcliff

to the

PRESIDENT AND FACULTY

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Having completed the prescribed course

of study in

MECHANICAL ENGINEERING.

CHICAGO, JUNE 15, 1905.

W.A. Ratcliff

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Analysis and design of a Power Plant for a proposed Department Store and office Building.

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BUILDING:

The building for which this power plant is designed will be fifteen stories above street level and three basements below, covering a half block, 160 ft. by 325 ft. An alley separates the building from the rest of the block.

The building is arranged for use by a department store, for seven floors above street level, and the two upper basements, and the space not needed in third, or lowest, basement for this power plant, which requires about 150 by 175 ft.

The rest of the building, eight floors, is divided into offices for rent.

Very well organized

POWER WANTED:

The power plant is intended to furnish heat, light, and power for the elevators.

LIGHTS:

For lighting the building both arc and incandescent lamps will be used in the store, but, in the offices, incandescent lights only.

ARCS:

In calculating the number of arcs needed, it was assumed that one arc would be placed in the center of each

17978

square formed by the pillars, as shown on plate I, first floor plan. All the store floors are practically alike, and the basement and upper sub-basement are figured at the same ratio for arc lights, while the lower sub-basement will have incandescent lights, one for each 100 sq. ft.

The location of incandescent lights in the offices was indicated by the architects on their drawings.

The following table shows the number of lights of each kind on each floor:

	Floors:	Arc Lights	Incand. Lights.
Store	Lower subbasement (40.360 sq.ft)		404
"	Upper "	80	
"	Basement	125	
"	First floor	90	
"	Mezzanine floor or balcony 1 lt. per 30 sq. ft. 5290 sq.ft		176
"	Mezannine floor or balcony offices		50
"	Second "	103	
"	Balcony between 2nd and 3rd floors	7	20
"	Third floor	93	183
"	Fourth floor	131	122
"	Fifth floor	90	60
"	Sixth floor	125	90
"	Seventh floor	83	40
Offices	Eighth floor		330
"	Ninth floor		380
"	Tenth floor		380
"	Eleventh floor		475
"	Twelfth floor		475
"	Thirteenth floor		475
"	Fourteenth floor		475
"	Fifteenth floor		217
	Total -	927	4352

As practically all the arcs will be needed for lighting the store at 5:30 P. M. in the short day season, or at the peak of the load, it is assumed that 95% of them are in service at that hour, the remaining 5% out of service for various reasons; hence the load will be 95% of 927, or 880 arcs. The enclosed arcs taking 5 amperes at 110 Volts are to be used with multiple distribution. This requires 110 x 5, or 550 Watts per lamp and for the 880 arcs it will be 484,000 Watts. Allow 1% for wire loss and the total power required is 488,840 Watts which from the formula $I = \frac{P}{E} = \frac{488840}{110}$ = 4444 amperes required for the arc lights.

INCANDESCENTS.

For incandescent lights, calculations on about one hundred office buildings show the absolute peak does not exceed 70% of the total wired incandescent lamps. Hence here there will be 70% of 4352, or 3045 lights in use at the peak. Each lamp requires 1/2 ampere at 110 volts, or 55 Watts per lamp, which for the 3045 lamps is 167600 Watts and adding 1% for wire loss, gives 169276 Watts, or 1530 amperes required for incandescent lamps.

LOAD CURVES.

The average lighting load-curves are shown on Plate II.

During the brighter part of the day, the two rows of arcs nearest the street windows are not needed, as daylight will suffice for lighting that space. These will come into use about 2:30 or 3:00 P. M., while the other arcs have been in service since 7:00 A. M. The peak will be reached about 5:30 P. M.

Probably no arcs will be in use during the night, as the incandescent lamps will supply what light is needed.

The incandescent light curve was obtained from the Engineering Magazine, January and February, 1903, and is the curve for the largest office building in New York City. This curve was modified slightly to suit the present case.

The peak occurs at 5:30 P. M., after which time there is a rapid drop until 7:30 P. M., and thereafter a fairly continuous night load appears.

The ordinates of the two curves were added, giving curve No. 3. The peak of this curve represents 6080 amperes, or 669 K. W.

It is possible for the engines and generators to run for about an hour, at 50% over their rated load; hence the rating of the generators required to carry the load at the peak will be 669 ÷ 150%, or 446 K. W.

MACHINES NEEDED.

Three 150 K.W. machines will carry this load. Two of the machines will carry the load from 7.00 A. M. to about 2.00 P. M. when the load is about 370 K. W. which is 23% over the rated load for the two machines. The third machine may then be started and all three will be running at 18% under their rated load- which will be reached at about 3.30 P. M. By 4.30 P. M. the machines will be 25% overloaded. By 5.30 P. M. under the 50% possibility aforementioned, the engines will reach the peak of the load, and carry it for a short time, until closing the store allows a decline toward the night load.

This night load will be carried by a 75 K. W. machine in service from 7.30 P. M. to 7.00 A. M.

One reserve engine and generator of 150 K. W. capacity will be installed to insure continuity of operation and permit other machines to be laid up for repairs.

ENGINES.

Tests on simple and compound engines show that the compound engine, working under a pressure of 125 to 150 lbs per square inch, gives better results in steam consumption than does the simple engine. For sake of efficiency and economy of operation in this plant, the tandem compound type of engine was

chosen. The 150 K. W. units are 14 x 22 x 18 Ball Engine Co.'s tandem compound engines, direct connected to Western Electric Generators. The 75 K. W. unit is an 11 x 18 x 14 Buffalo Forge Co.'s tandem compound engine, direct connected to a Bullock generator.

ELEVATORS.

A large part of the power in this plant will be used in the elevator service.

Provision is made for 42 passenger and freight elevators and one Van Elevator. Twelve elevators are for use of tenants of the offices and thirty for the store.

Vertical cylinder hydraulic elevators operating on a water pressure of 150 lbs per square inch will be installed.

OFFICE ELEVATORS.

Of the twelve office elevators, eleven will run between first and fifteenth floors, and one from lower sub-basement to fifteenth floor, which give rises of 217 ft. and 261 ft. respectively.

These elevators will be geared 6 to 1, giving piston travel of 36.2 ft. and 43.5 ft respectively. The cars will carry loads of 3000 lbs each and run at a maximum speed of 400 ft. per minute.

It has been here assumed that the lifting apparatus has an efficiency of 50%. Hence the size of cylinder required for each car is $\frac{3000 \times 6}{150 \times 50\%}$ or 160 square inches, which corresponds to a diameter of 14-1/4 inches.

One foot of elevator cylinder is $\frac{160}{144} \times 1.$ or 1.11 cubic feet, the equivalent of 8.33 gals. of water.

While the maximum speed of cars is 400 ft. per minute, it may be safely assumed that the average speed, including stops, will not exceed 50% of that figure.

Hence the velocity of the plunger is $\frac{400 \times .50}{6}$ or 33.3 per minute.

The cars will be under control of starters, hence one car of each group will always be held at bottom of shaft.

Supposing ten cars to move at one time, they will require 10 x 8.33 x 33.3 or 2770 gals. of water per minute.

STORE ELEVATORS.

Of the 30 store elevators, twenty three are for passenger service, and seven for freight. The former are arranged in groups of four or five together, in various parts of the store, as shown on first floor plan on Plate I, and all under direction of starters.

It is possible for any eighteen cars to move at

one time. Each car is intended to carry 2000 lbs., and is geared at 4 to 1, and run at maximum speed of 250 ft. per minute. The average speed, including stops, will not exceed 50% of this.

Allowing an efficiency of 50%, as before, the area of cylinder for each is $\frac{2000 \times 4}{150 \times .50\%}$, or 107 square inches; that is, the diameter is 11-3/4 inches. One foot of Cylinder length is $\frac{107}{144} \times 1.$, or .743 cubic feet which equals 5.57 gals of water. Hence assuming that 18 elevators start at one time they would require 18 x 31.1 x 5.57, or 3140 gallons of water.

The seven freight elevators are located in one group and any six may be assumed to move at one time. The cars will have maximum speed of 200 ft. per minute and carry 4000lbs. each, being geared 4 to 1.

Assuming average speed as 50% of maximum the cylinder area for each car is $\frac{4000 \times 4}{150 \times .50\%}$, or 213 square inches, and diameter is 16-1/2 inches. One foot of cylinder will equal $\frac{213}{144} \times 1$, or 1.48 cubic ft. which equals 11.1 gallons.

Velocity of piston will be $\frac{200 \times .50}{4}$, or 25 ft. per minute.

If six elevators move at a time, they will require 6 x 11.1 x 25, or 1660 gallons of water per minute.

VAN ELEVATOR:

The Van elevator will be operated by a separate pump,

on 250 lbs. pressure and will be dealt with later.

Assuming the heaviest condition, that the maximum number of elevators possible all start at one time (both office and store), the pumps will be obliged to furnish the following amount of water per minute:

WATER NEEDED:

For Office Elevators	2770	gallons per minute.
" Store - Passenger	3140	" " "
" " - Freight	1660	" " "
Total -	7570	

PUMPS:

Practically the only pump available to handle such large quantities of water, are of the high duty, compound, fly-wheel type. It is decided to use three Laidlaw-Dunn-Gordon pumps of this type, each having one high pressure and two low pressure steam cylinders.

The pumps are 17-3/4" x 22" x 22" x 12-1/4" x 30" each of which has a capacity of 2550 gallons per minute, when running at speed of 56 R.P.M. These pumps are designed to operate at 150 lbs. per square inch steam pressure, and have a mecnahical efficiency of 85%.

No reserve pump of this type will be installed as requirement for the pumps have been computed on a very liberal basis, and in case of accident to one, the load could be carried

by overloading the other two, and also running the van and night duty pumps.

NIGHT DUTY PUMPS:

It is contemplated that three elevators would run at night, one in each corridor of Office building, and one in the store.

As previously stated the Office elevators will be operated by cylinders having areas of 160 square inches, and each will require 277 gallons of water per minute. Should both start at one time they will require 277 x 2, or 554 gallons per minute. The Store elevator has a cylinder area of 107 square inches and requires 174 gallons per minute. Hence the maximum amount of water required of the night duty pump is 554 + 174, or 728 gallons per minute.

A Worthington Compound Duplex Steam pump 14" x 20" x 12" x 10" was chosen, capable of delivering 750 gallons, at 75 strokes per minute and 1000 gallons at 100 strokes per minute.

VAN ELEVATOR AND PUMP:

The Van elevator is intended to carry heavy weights, such as vans, safes, etc., not exceeding 10,000 lbs. weight.

It will be geared 4 to 1, and will have a maximum velocity of 150 ft. per minute. The efficiency of the lifting apparatus is assumed at 50%. The area of cylinder required will be $\frac{10000 \times 4}{250 \times .50\%}$, or 320 square inches which corresponds to

diameter of 20 inches. One foot of cylinder length will equal $\frac{320}{144}$, or 2.22 cubic ft. which means 16.7 gallons of water. The velocity of piston is $\frac{150}{4}$, or 37.5, and it is assumed that the average velocity will be 50% of this figure, or 18.75 ft. per minute. Hence the pump will be required to deliver 18.75 x 16.7, or 313 gallons per minute.

For water pressures over 150 lbs. per square inch the outside-packed-plunger type of pump is the most satisfactory, hence a Knowles Compound Duplex Pump 9" x 14" x 7" x 12" was chosen for this work.

DISCHARGE AND PRESSURE TANKS:

The volume of the discharge tank was made 3.5 times the total volume displacement of all elevator cylinders.

The total piston displacement is 1054 cubic feet hence the discharge tank is 3.5 x 1054, or 3180 cubic feet. This tank is to be constructed of 1/4 inch boiler iron, and made thoroughly water tight, but will not be obliged to stand any pressure other than that due to weight of water. Its size is 14 x 21 x 10 ft. and it is located in the basement, as shown on project Plate II.

The pressure tanks are located on the roof of the building. It is commonly figured for moderate sized plants that the pressure tank shall have a capacity of 4 cubic feet for each cubic foot of elevator piston displacement; but owing to

the great number of elevators here, only 2 cubic feet of tank capacity for each cubic foot of elevator displacement, was deemed necessary. Hence the pressure tanks have a capacity of 2 x 1054, or 2108 cubic feet.

About one-third of the capacity of these tanks is air, and they are made air tight and able to withstand pressure of 150 lbs. per square inch.

BOILERS:

The boiler plant is required, at the peak of the load, to furnish steam for the three 150 K.W. generating units, the three high duty pumps, and all steam auxiliaries.

The combined efficiency of engines and generators is assumed at 80% and as 1 K.W. is equal to 1.33 H.P., the total Horse Power will be $\frac{3 \text{ x } 150 \text{ x } 1.33}{.80\ \%}$, or 750 engine H.P.

A liberal figure for the steam consumption of the Compound steam engine is 30 lbs. per H.P. per hour. Therefore, these engines will require 750 x 30, or 22,500 lbs. of steam per hour.

The manufacturers of the pumps give 85% as their mechanical efficiency. Knowing this, the horse power of the pumps was calculated as follows:

Water pressure 150 lbs.

Area of each water cylinder 117.86 square inches.

Length of stroke 2.5 ft. Number of strokes per min. 56.

Mechanical efficiency 85%. Number of water cylinders 3

Hence, the H.P. of each pump is:

$$\frac{3 \times 150 \times 117.76 \times 2.5 \times 56}{33000 \times .85\%}$$, or 264.5 H.P. and for three pumps there will be 794 H.P..

These pumps have a steam consumption of 27 lbs. per H.P. per hour, so they will require 794 x 27, or 21,400 lbs. of steam per hour.

Hence steam required for 3 engines 22,500 lbs.

and " " " 3 elevator pumps 21,400

Total - 43,900 Lbs.

It has been found that the steam consumption of auxiliaries is about 10% of the steam required for the main units, hence adding 4390 to above total shows 48290 lbs. of steam required per hour.

One boiler H.P. is equivalent to 34.5 lbs. of water evaporated from and at 212° Fahrenheit, so that the total above will require $\frac{48290}{34.5}$, or 1400 H.P. at the peak of the load.

However the boilers may be forced beyond their rating to carry the peak, without loss of efficiency, so it was decided to install four 300 H.P. boilers or 1200 B.H.P. to carry the load.

One 300 H.P. reserve boiler was added to enable any of the other boilers to be laid up in case of accident, or for cleaning. The make of boilers chosen is the Babcock and Wilcox

vertical header type.

MECHANICAL STOKERS

Roney Mechanical stokers are to be installed with the boilers, and they will be operated by two 4-1/2" x 4" Westinghouse standard engines. A view of the boiler and stoker is shown on Plate IV.

CHIMNEY

The height of chimney will be 300 feet, and its area was determined from a table in Kent's Mechanical Engineer's Pocket Book, page 735, based on the formula

$$H.\ P. = 3.33\ (A-0.6\sqrt{A})\sqrt{H}.$$

Where A. is the area in square feet and H. is the height in feet. For a height of 300 ft. and commercial boiler house power of 1201, the required chimney area is 23.76 square ft., corresponding to a diameter of 66 inches. This is based on the assumption that 5 lbs. of coal are burned per horse power per hour.

The chimney will be 66 inches inside diameter, lined with 2 inch vitrified brick, and a 2 inch air space left between the brick and the shell. This requires the shell to be 74 inches in diameter. It is to be constructed of steel 9/16 inch thick for first 50 ft. and varying 1/16 inch less for each succeeding 50 ft.

FEED PUMPS

The feed pumps will be required to pump 48290 lbs. of water per hour, that being the amount needed at the peak of the load. This is equal to 96.5 gallons per min. Two 7-1/2 x 5 x 6 Deane Duplex Steam pumps will be installed, each having a capacity of 100 gals. per min. when running at rated speed. The installation of two pumps insures against shut down of plant in case of accident, to either.

FEED WATER HEATER

The feed water heater to be installed is a 7 x 12 ft. horizontal open pan heater, manufactured by Wm. Baragwanth & Son, and is designed to heat 100 gallons of water per min. from 60° to 210° F.

HEATING:

The system for heating this building above street level will differ from that for heating below. Above street level the Webster vacuum system will be used; the basements will be heated by indirect method, that is, air will be drawn into a closed room in the upper sub-basement, in which are located coils of steam pipes. After the air of the room is heated, it will be forced through ducts to various parts of the basements. This will be done by five 66" Buffalo Forge Co's fans, each belted to

to a 3-1/2 H. P. motor.

As the basements have no glass or exposed walls, the amount of radiating surface was calculated on the basis of cubical contents only.

Kent, in his "Pocket Book", page 537, states that one square foot of radiating surface will heat 100 cubic ft. of space in partially exposed rooms. However, these basements are not exposed on any side, hence it might be assumed that under this condition, the 100 cubic ft. could be increased 50%, or one square ft. of radiating surface to heat 150 cubic ft. of contents. Kent's statement, however, is based upon the direct system of heating, and must be modified for indirect work.

In Babcock & Wilcox book "Steam" page 91, they state that when the indirect system is employed, from 50 to 100% more radiating surface is required, than under the direct system. Hence the 150 cubic ft. of radiating surface should be decreased, and 100 cubic ft. is the figure adopted.

The cubic content of the basements is 1,84 2,000 cubic ft. and with the above 100 cubic ft. assumption, 18,420 square ft. of radiating surface will be required.

It is commonly figured that 3/10 lbs. of steam will be condensed per square foot of radiating surface per hour,

and for the 18420 sq. ft. it will be 5530 lbs. per hour, or 93.8 lbs. per minute, which is the equivalent of 11 gallons of water per minute.

For the part of this building above street level the number of feet of radiation, and the amount of steam condensed per hour, were calculated from Carpenter's formula

$$R = \frac{1}{280}\left(\frac{C}{55} + G + \frac{W}{4}\right)\frac{80}{.90},$$ in which

R is number of feet of radiation

C = cubic ft. of content

G = square ft. of glass area

W = square ft. of wall area

This formula as it stands is based on the assumption that there shall be a temperature of 70° F. maintained within the building, when the temperature without is 10° below zero; and that 280 heat units will be given up per hour for each square foot of radiating surface.

Now the ground area of the store part of building is 51,800 sq. ft., height 1st to 8th floor inclusive, 115.5 feet, hence cubic content is their product, or 5,980,00 cubic feet. Ground area of office part is 38,150 square feet. Height, 8th floor to roof inclusive, 92 ft., cubic content, the product of these or 3,510,000 cubic ft. Hence the "C" in Carpenter's formula, here is 9,490,000 cubic feet,

and "W" or wall surface is 160,250 sq. ft. and "G", or glass surface is 105,620 sq. ft., from which

$$R= \frac{80}{280x90} \left(\frac{9,490,000}{55} + 105.620 + \frac{160.250}{4} \right)$$

which gives 100,900 square ft. of radiating surface, and this multiplied x 3/10 lbs. of steam gives 31,300 lbs. steam condensed per hour, equal to 3640 gals. water per hour, or 60.6 gals. per min. Adding the 31,300 lbs. steam required per hour for direct system and 5530 " " " " " indirect system - the total for building is 36,830 lbs.

One B. H. P. will evaporate 34.5 lbs. per hour; hence there will be required for this building $\frac{36830}{34.5}$ or 1068 B. H. P. But already 1200 B. H. P. has been provided for steam to engines and pumps, and hence no additional boilers need be installed for heating, as the exhaust steam will be sufficient to heat the building.

VACUUM PUMPS

These are required to handle the condensed water from the radiating surface, together with the air which accumulates in the radiator. The latter was assumed as having four times the volume of the water.

The condensation from the indirect system was found to be 11 gallons per min. and from the direct system 60.6 gallons

per min., a total of 71.6 gals. per min.

Four times this quantity of air will be 286 gallons. Hence the pumps will have to handle the sum of these figures, or 357.6 gals. per min.

Two Knowles 6" x 9" x 10" "air or vacuum" pumps were chosen for this work.

A Returns Receiver tank 3 ft. diameter and 6 ft. long, will be installed, into which the return condensation will be pumped, and from which it will gravitate to the Feed Water Heater, as shown on Plates III and IV.

HOUSE PUMPS

To determine the size of House Pumps needed, an allowance of .4 gallons of water per square foot of store and office space for 24 hours was made.

Area 1st and 2nd basements each	61,200	sq.	ft.	=	122,400	sq.	ft.
" 1st floor	34,518	"	"	=	34,518	"	"
" 2nd to 7th floors each	47,378	"	"	=	284,000	"	"
" 8th to 15th " "	28,000	"	"	=	122,400	"	"
Total area				=	664,918	"	"

This multiplied by .4 gals. gives 265,967 gals. per 24 hours, or 185 gals. per min.

Two Smith-Vaile 7" x 8", single acting triplex pumps, each with capacity of 160 to 240 gals. per min. were chosen, and

each pump will be driven by a 10 H. P. motor, connected to the pumps by a chain belt. These pumps will run at a speed of 50 R. P. M.

FIRE PUMPS

Two Worthington duplex steam driven "Underwriters Fire Pumps" will be installed for fire protection. They are 14" x 7-1/4" x 12" and each will pump 500 gals. of water per min. The house and fire pumps will obtain water from a basement house tank 6 x 16 x 10 ft., which equals 960 cubic ft.

Water is to be delivered to this tank from the city main and passing through a water meter. The house pumps pump from this tank to a roof tank, from which the water will gravitate to the various fixtures of the building.

PIPING

Flanged wrought iron steam piping will be used throughout, and is to be of proper strength to carry steam at a pressure of 150 lbs. per square inch.

Steam comes from the boilers through 8 inch long-radius-bend feeders, to the 14 inch header running nearly the length of the boiler room.

A 9 inch line of piping in the form of a loop is taken off from this header and passes around the engine room.

The engines and pumps take steam from this loop.

The size of all piping to be used in this plant was determined by the "Table of Equation of Pipes", page 101, of Babcok & Wilcox's Catalogue "Steam", knowing the size and number of leads to be taken from any line of pipe.

Austin steam separators, vertical type, are to be placed in the branch to each engine and pump, as shown in the detailed elevations.

Exhaust piping is to be laid in trenches of 18" to 24" square according to size of pipe. Two 12" lines of exhaust pipe will be put in, one running from Elevator pumps, and the other from the engines and auxilliaries.

These exhaust lines enter an expansion tank 4 ft. in diameter and 12 ft. long, From this tank two 15" risers are taken, one going to the heating loop in the attic and the other to the exhaust head on the roof.

The arrangement and size of all piping is clearly shown on the detailed plan and elevations.

ELEVATOR PUMPS PIPING

The three high duty elevator pumps each have a suction opening of 18 inches diameter and discharge of 14 inches. From the equation of pipes, it was found that three 18" pipes

were equivalent to one 36" pipe, and hence the pipe from discharge tank to the pumps is to be 36" diameter and will be cast iron. Similarly, the discharge pipe must be 20" diameter and will be wrought iron.

SEWAGE EJECTION

As this power plant is located in the lower sub-basement, 44 ft. below street level, it is necessary to provide means of raising the basement sewage to the level of the sewer in the street. For this purpose two Shone Ejectors will be installed in a pit at bottom of which will be the lowest point in the basement.

The blow-offs from the boilers empty into the blow-off tank at rear of the boilers, and from that tank the water gravitates to a cooling pit. The outlet from this pit leads directly to the ejectors and is about four feet from bottom of the pit, thus maintaining that depth of water in the pit, which will allow the water to become cool before flowing to the ejectors.

All low pressure drips are to be carried in the exhaust pipe conduits, and will empty into a tank under the floor in which they will flow to the cooling pit above mentioned, and from this to the ejectors. These ejectors are operated by compressed air. Air is supplied to a pressure tank at about 25 lbs. pressure, by

either of two motor-driven horizontal air compressors and is piped from the tank to the ejectors. When the ejectors fill with water, a float valve admits air from the tank, which forces the sewage up to the city sewers. The starting and stopping of the motors, driving the air compressors, is automatically accomplished by electrically connected pressure guages and solenoids. Thus, when the pressure in the air tank falls, the hand of the guage moves around the dial and comes in contact with a platinum point, closing the circuit through the solenoid, which moves the iron core up, and in turn closes the motor circuit, and starts the machine. As the pressure in the tank increases, the hand of the guage is moved until it comes in contact with another platinum point on the dial, breaking the circuit through the solenoid, and thus opening the motor switch, and stopping the machine.

All high pressure drips will be conveyed through pipes to an enclosed tank in the same pit with the low pressure drips cooling tank. From that tank it will be returned to the boilers by means of a Holly Loop located in the first basement.

This concludes the analysis and description of this plant and appurtenances to be installed. It is evident that this design does not contemplate low first cost as principal

consideration; but rather to obtain efficient work and insure continuous unfailing operation; as well as to provide against early or rapid deterioration, and therefore keep the cost of maintenance at lowest figure possible.